

Exoplanet Science: Detections, Biomarkers, & Prospects

Wesley A. Traub

Chief Scientist, NASA's Exoplanet Exploration Program

Jet Propulsion Laboratory

California Institute of Technology

Symposium on "Astronomical Pioneering:
The Implications of Finding Other Worlds"

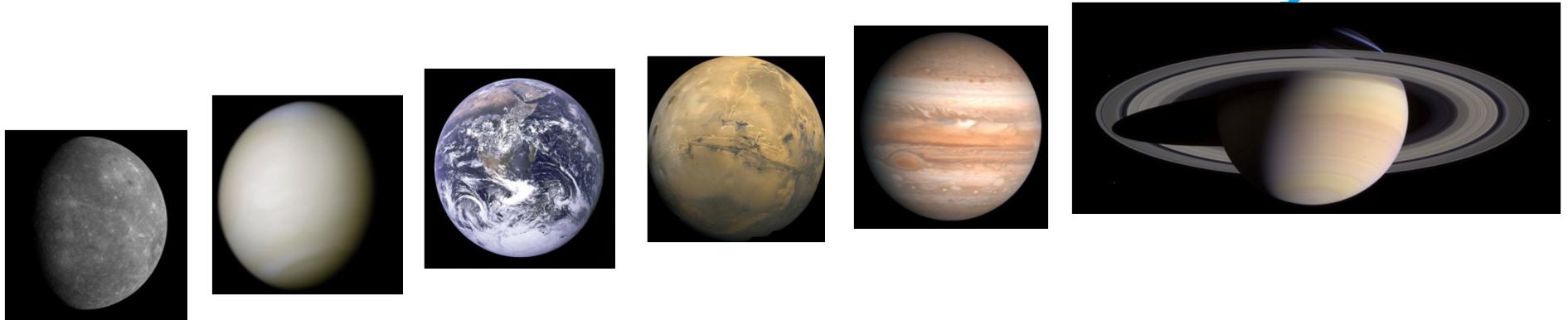
AAAS Annual Meeting

Washington DC 20 February 2011

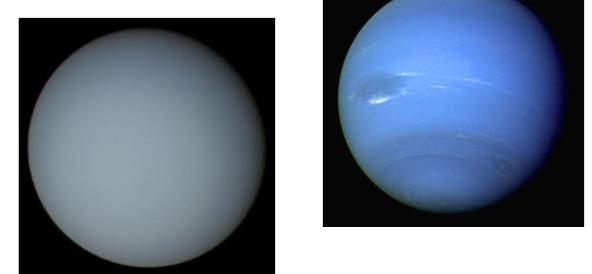
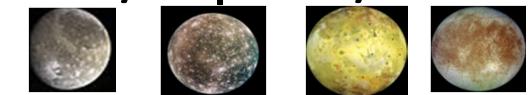
Outline of Talk

- Exoplanets today
- Signs of Life
- Future research

Planet Discoveries in the Solar System



- <1000 BC: Mercury/Venus/Earth/Mars/Jupiter/Saturn
- 1610: Moons of Jupiter, by Galileo
- 1655-86: Moons of Saturn, by Huygens & Cassini
- 1781: Uranus, by Herschel
- 1846: Neptune, by Galle & LeVerier
- 1930: Pluto, by Tombaugh
- <2011: Over 205 planets, moons, & dwarf planets



Exoplanets Are Discovered!

- 1989: D. Latham et al., HD 114762
- 1992: A. Wolszczan & D. Frail, PSR 1257+12
- 1995: D. Queloz & M. Mayor, 51 Peg
- 1995: G. Marcy & P. Butler, 51 Peg

Astrometry, Imaging, Radial Velocity

Transits

5 Ways to Find & Characterize Exoplanets:

- Radial velocity 

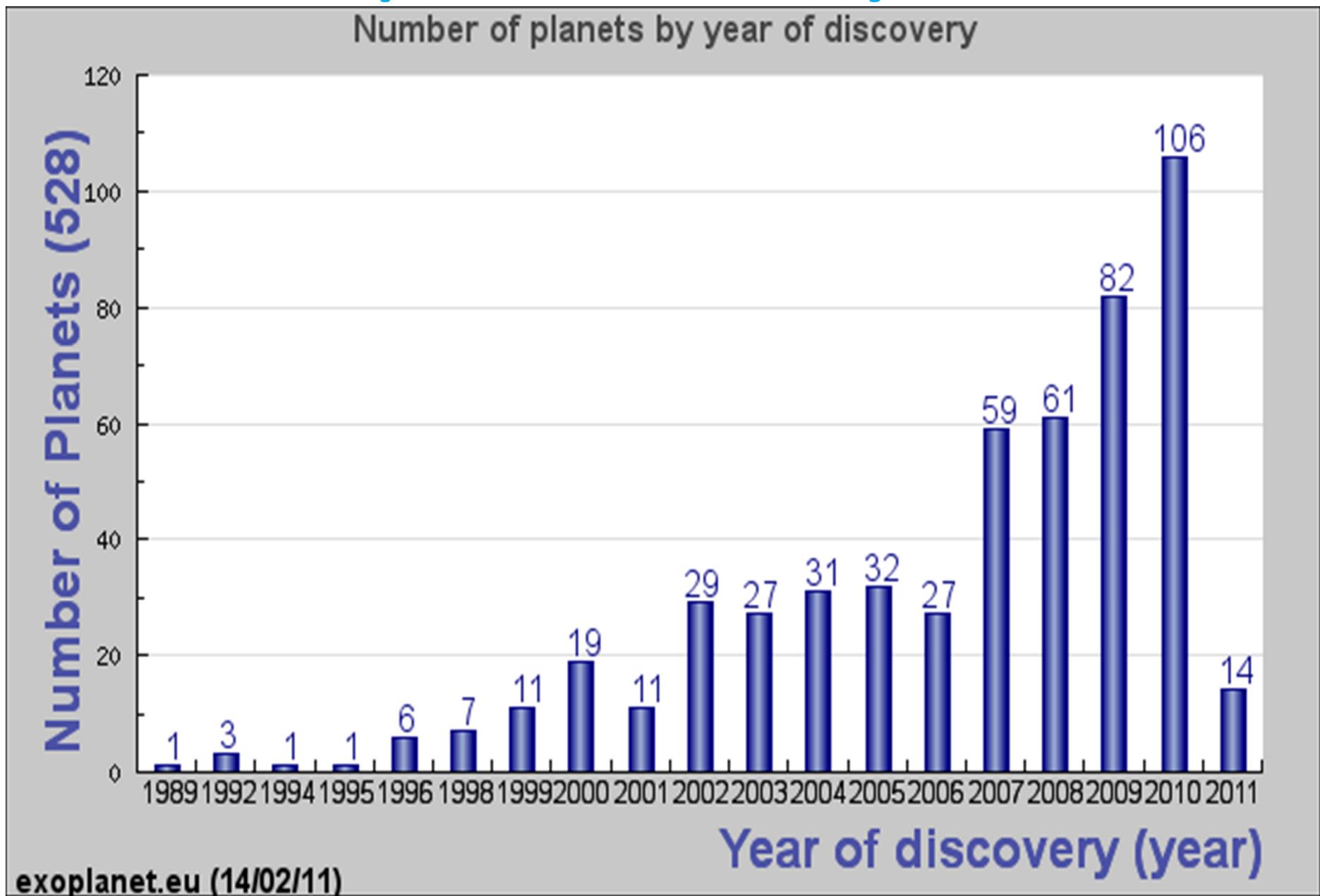
- Transits 

- Microlensing 

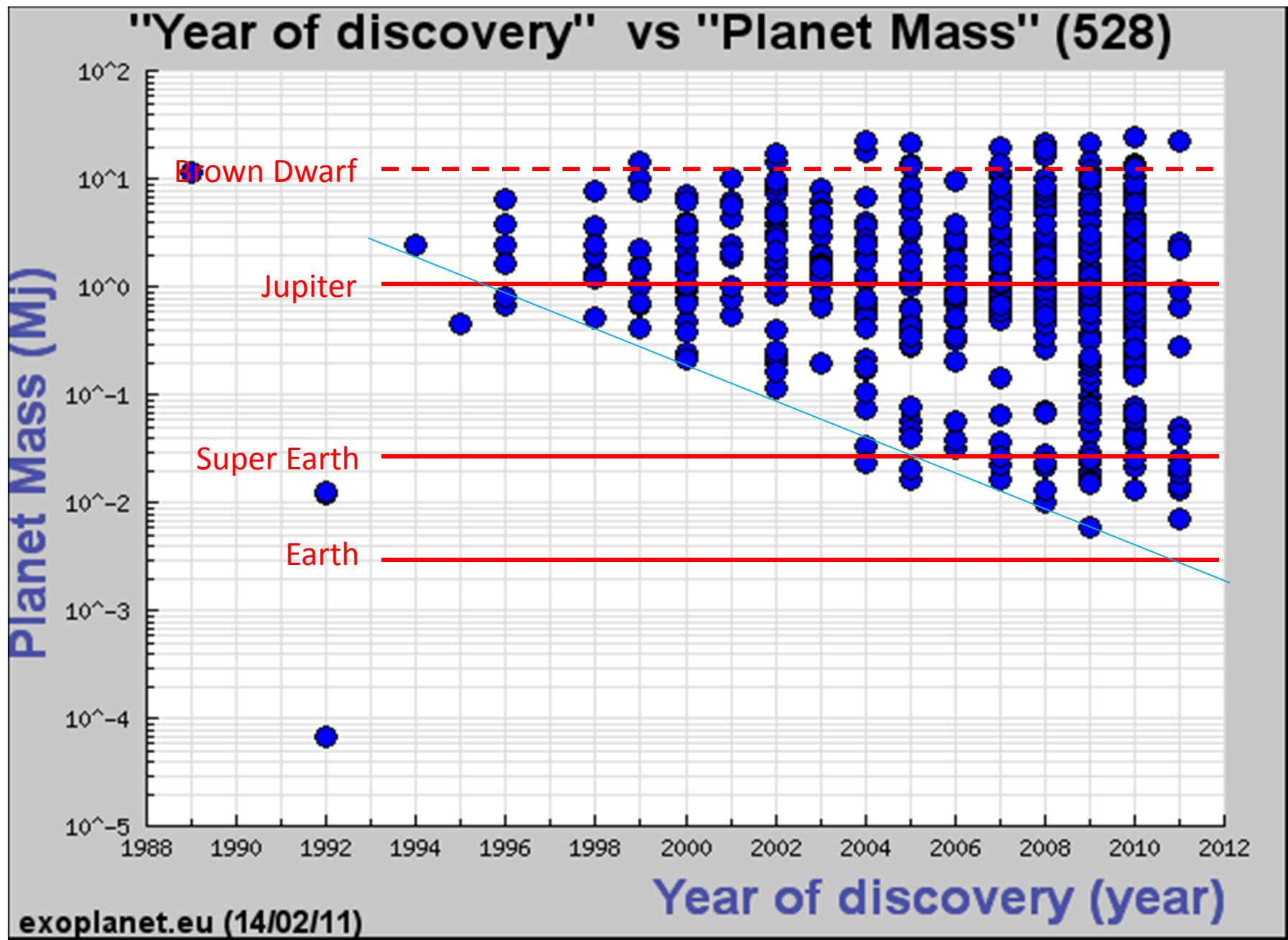
- Imaging 

- Astrometry 

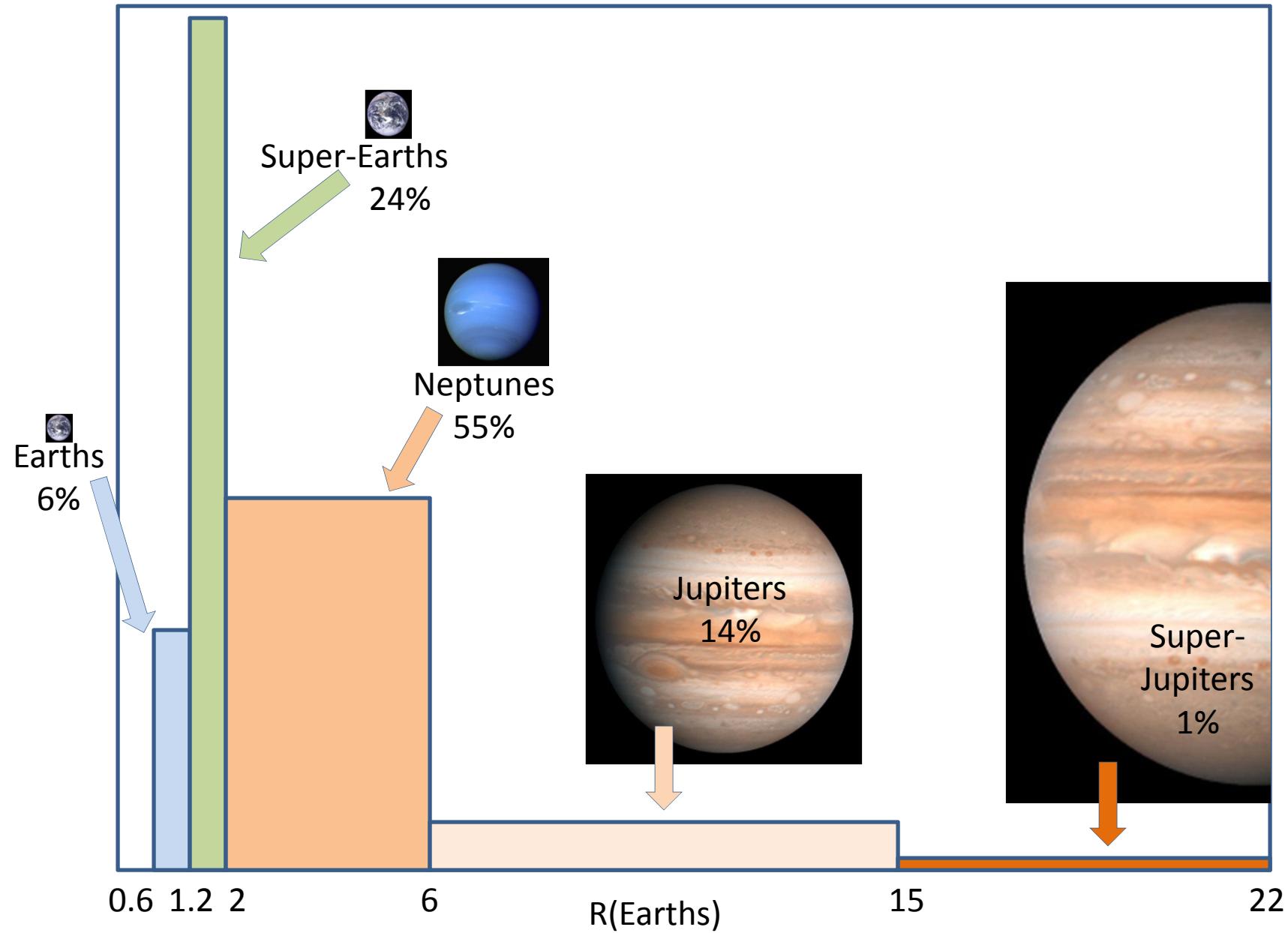
Exoplanet Discovery Rate



David & Goliath



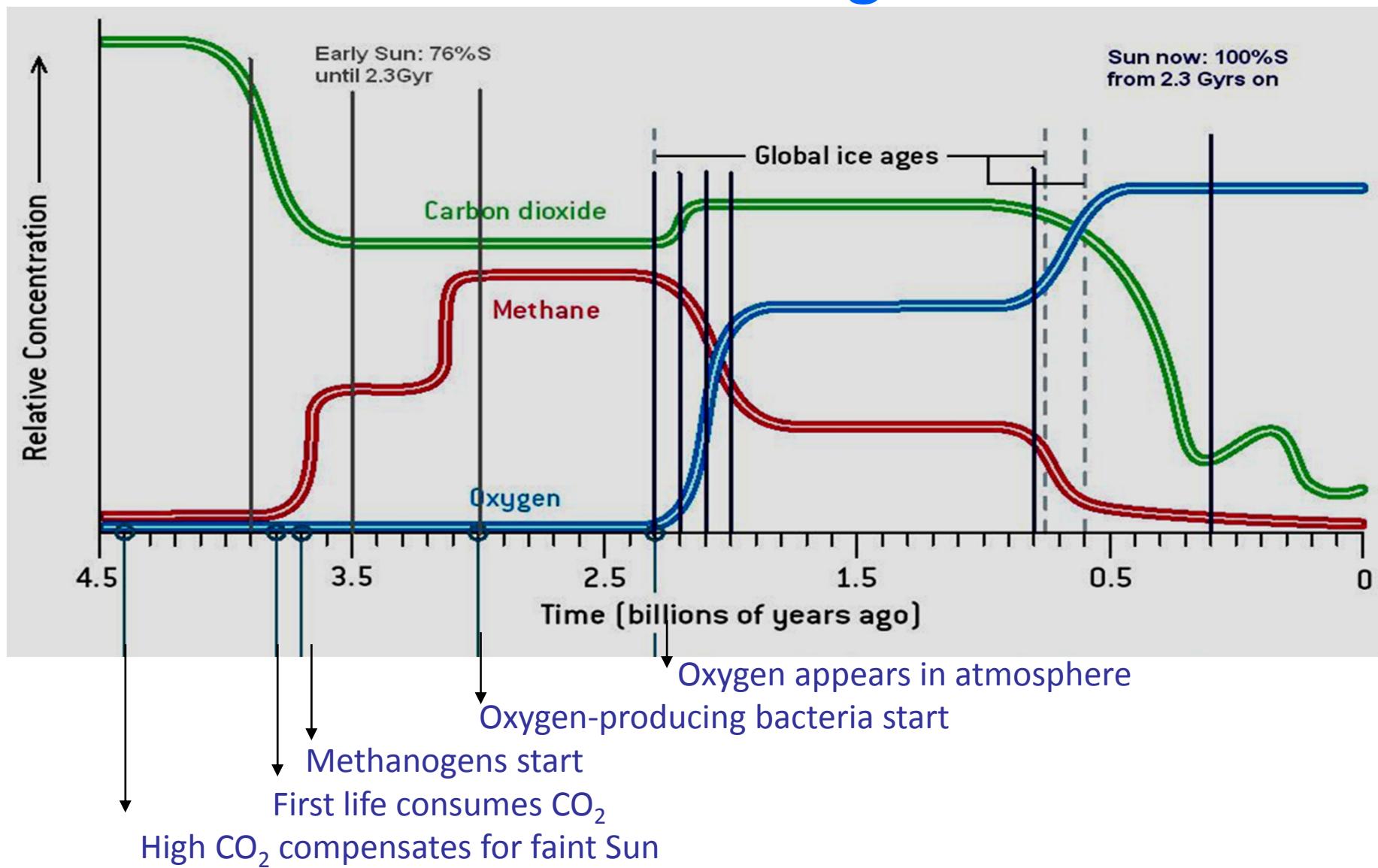
Kepler: 1235 Candidate Exoplanets



Signs of Life: Microbes to Mega-cities

- Life needs a surface or ocean (so terrestrial planets only)
- Life needs liquid water (e.g., NH₃ is unlikely)
 - So we search in habitable zones (0 to 100 C)
 - And for H₂O vapor
- Life is carbon-based (e.g., Si is unlikely)
 - And we search for CO₂ (plant food)
- Plant life produces large amounts of O₂ (>>photochemistry)
 - So we search for strong O₂ signatures, also O₃
- Visible & near-infrared spectrum (O₂, O₃, H₂O, CO₂, CH₄) excellent
- Mid-infrared spectrum (O₃, CO₂, CH₄) good
- Earth's spectrum has been the same for ~300 Myr

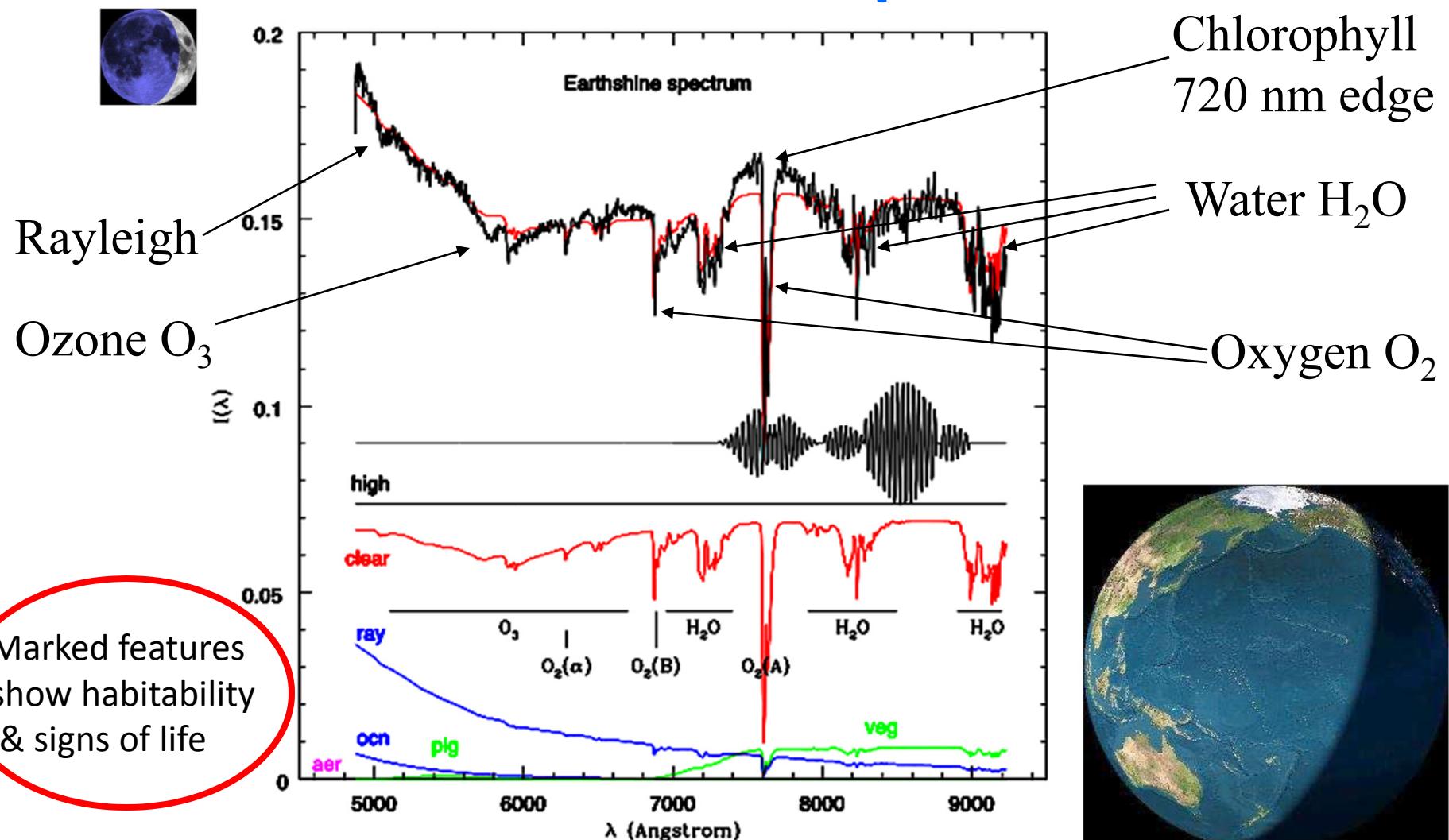
Earth Over Geologic Time



Traub

Refs: Kasting, Scientific American;
Kaltenegger et al, 2006; Holland 2006

Visible Earthshine Spectrum



- Observed Earthshine, reflected from dark side of moon.

Woolf, Smith, Traub, & Jucks, ApJ 574, p.430, 2002

Signs of Life: Intelligent Civilizations

- Radio/TV signal search (SETI) started in 1960
 - Big sky, big spectrum, searching continues



- Laser beam search (optical SETI) started in 1998
- Optical fibers reduce these leaks
- If a beacon is found, it is likely an intentional signal

Future Exoplanet Research

- Transits: Kepler & Corot active; others proposed
- RV: active, $1.0 \rightarrow 0.1$ m/s goal
- Microlensing: active, statistics to snowline
- Exozodi: active (Keck & LBTI)
- SETI, active
- WFIRST: microlensing/DE/surveys, 2010s (Astro2010)
- Imaging: discovery/spectra, 2020s (Astro2010)
- Distant future:
 - infrared imaging
 - pictures with 1000-km telescope array
- *Prediction: 5 nearby terrestrial planets by 2030*